Stanford Professor Donald Kennedy
on Science Policy Page 35

Chemical & Engineering NEWS

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CLASSROOM CRISIS

Declining enrollments, teacher shortages threaten science education
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Cover: Teacher Douglas Halstead conducts chemistry class at Evanston Township (Ill.) High School. Photo by C&EN's Ward Worthy

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In an unusual move to halt what it considers a one-sided feedstock cost advantage, ICI has begun legal action against the U.K. government. The flap has been sparked by clause 129 of the government's Finance Bill now nearing the final stage of its passage through Parliament.

The clause would tax North Sea-derived ethane for ethylene production by BP Chemicals, Esso Chemicals, and Shell Chemical U.K. on the basis of a low "internal" transfer price of the gas set by their oil company parents. The net result, ICI executives claim, is that the ethylene ICI makes by cracking naphtha would be more costly than ethylene made by the others.

There's an irony to the development. Not so long ago, ICI was linked with BP, Esso (Exxon's U.K. subsidiary), and Shell in exhorting the British government to limit North Sea gas availability to established U.K. olefins producers—themselves—and not make it available to others, such as Dow Chemical, which expressed an interest in entering the picture. BP Chemicals currently is planning to convert its cracking operations at Grangemouth, Scotland, to ethane feedstock. Esso and Shell are pushing ahead jointly with an ethane cracker at Mossmorran, also in Scotland. When on stream in about three years, it will have an annual ethylene output capability of 1.1 billion lb.

If ICI wins its case, the economics on which BP Chemicals, Esso, and Shell have based their plans will be thrown into serious question. For their part, on the other hand, ICI managers say they aren't bluffing, and that they will close down Wilton if judgment goes against them. Union leaders believe the claim and already have voiced concern about the impact this would have on the country's already severe unemployment situation. □

Surprise early pickup forecast for polyolefins

U.S. polyolefins—the most important plastics—may not really be the basket case that producers have been saying they are. Indeed, actual plant operating rates may be high enough to spark a significant early improvement in earnings for manufacturers, possibly within a year, according to a controversial new forecast by Oppenheimer, a New York City-based securities firm.

Says Richard A. Derbes, a securities analyst with Oppenheimer, "We believe that supply/demand for the olefin plastics [low- and high-density polyethylene and polypropylene] is not a disaster, because there has been a significant shrinking of capacity over the past year." He adds, in a new report on the plastics industry, "The implication is that operating rates are much higher than is generally perceived, and, as a result, we believe pricing and margins will improve over the next year."

The Oppenheimer report also covers polyvinyl chloride, polystyrene, and acrylonitrile-butadiene-styrene, all of which Derbes is pessimistic about because of depressed demand and low operating rates. But he says that if one subtracts capacity temporarily shut down, effective operating rates are substantially higher than the industry has been assuming.

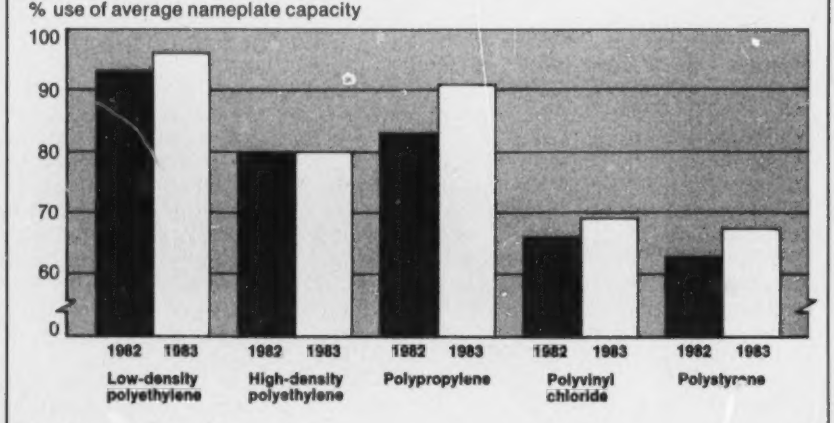
That is particularly the case with LDPE, according to Derbes, who thinks that "a major change has begun to evolve in the LDPE business." Among his arguments are that operating rates for LDPE are 85 to 90% on a nameplate basis and above 90% on an effective basis; nameplate capacity is presently close to 9.5 billion lb per year, and if the pricing situation does not improve in the third quarter, capacity could shrink as much as another 1 billion lb; demand will be up in 1982 because severe inventory liquidation in the second half of 1981 pushed production below consumption; and production may hit 8.5 billion lb in 1982.

Derbes believes that linear LDPE produced by Union Carbide's low-cost, low-pressure Unipol process already is beginning to make older, high-pressure process plants obsolete. That is particularly true, he says, as producers lose the advantage of low-priced ethylene or natural-gas-liquids feedstock. That will result in producers' finally deciding to shut down permanently capacity now mothballed or closed down for temporary maintenance. And that, in turn, according to Derbes, will strengthen polyethylene prices reasonably soon. In fact, he believes that pricing and profit margin improvement on polyethylene will be significant enough to prove a nice boost to producer earnings. He cites Dow Chemical and Union Carbide, in particular, as benefiting from an improvement in the polyethylene business, with their new Dowlex and Unipol processes.

Industry observers are intrigued by Derbes' pared-down capacity figures. But they part company over his predictions on production for the year. The prediction of 8.5 billion lb of production for LDPE, for example, seems quite high compared with an annualized 7.39 billion lb production rate through May using statistics from the Society of the Plastics Industry's Committee on Resin Statistics. Industry sources point out, in addition, that production tends to fall off in the third and fourth quarters. Some pessimists in the industry doubt that LDPE production will top 7.2 billion lb this year.

However, even with LDPE production at this annualized early rate, effective capacity use works out to an 87% rate—not bad for an industry that has been filled with gloom and doom for the past year or so. □

Plant use will be fairly high for polyolefins in 1982 and 1983



Source: Oppenheimer & Co.

Classroom crisis in science and math

Fewer precollege students are opting for science and math courses, resulting in growing public ignorance of technology; meanwhile a shortage of science and math teachers is worsening

Ward Worthy
C&EN, Chicago

For a problem to become a crisis, its time has to arrive. First come the scattered warnings of impending trouble from those closest to it. At that early stage, nothing much else happens. As the problem gets worse, the screaming gets louder—loud enough to gain the notice of people who, although not actually at the scene, nevertheless have an interest in the matter. Finally, if the problem gets bad enough and if the complainers are persuasive and persistent enough, it draws the attention of politicians and journalists. Then it's a crisis.

By that perhaps too cynical definition, a pair of long-brewing problems in U.S. education recently have achieved bona fide crisis status. One problem is that the public, by most objective measures, is becoming increasingly ignorant of things mathematical, scientific, and technological. The other, related to the first problem but distinguishable from it, is a current and worsening shortage of persons competent and willing to teach those subjects to students in elementary and secondary schools. For purposes of convenience, the two have been lumped into one official crisis, the crisis in precollege education in science and mathematics.

Convincing evidence of crisis status comes from a recent National Academy of Sciences (NAS) convocation on the subject in Washington, D.C. (C&EN, May 24, page 39). It was no gathering of deputies, administrative aides, assistant professors, and other lower-echelon people. Real stars were there, including Congressmen, Cabinet secretaries, key bureaucrats, and prominent scientists, educators, and businessmen. President Reagan didn't attend, but he sent a message.

The participants at the convocation all agreed that there indeed was a crisis. They didn't all agree on what should be done about it; in particular, they expressed deep philosophical differences as to who should pay for what. They all did agree that something had to be done, and they arrived at a reluctant consensus that dealing with the crisis will require concerted efforts by government at all levels, colleges and universities, local schools, professional organizations, and private enterprise.

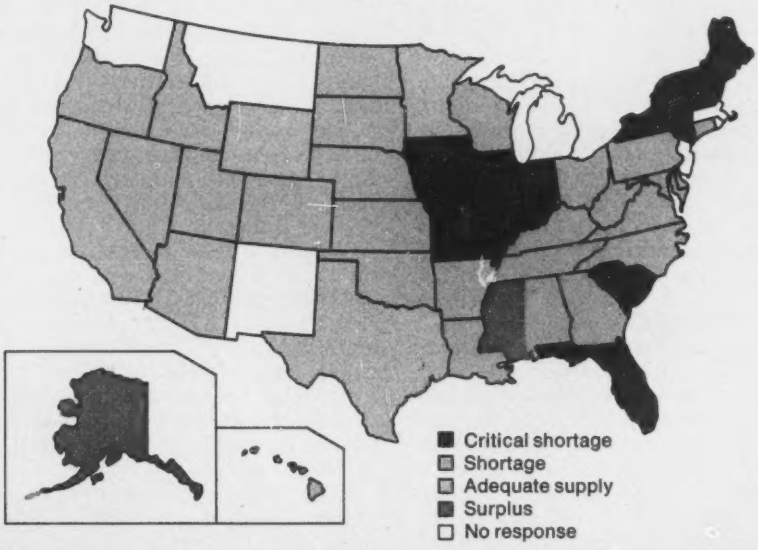
NEWS ANALYSIS

In fact, efforts to alleviate the precollege science/math crisis have begun already, although so far they aren't very concerted. If the taxpaying public also can be convinced of the need for action and financial support—not easy, in the current U.S. economic and political climate—they may succeed. It's to be hoped that these efforts will aim not just at quick fixes but also at grubbing out the roots of the problems. After all, the U.S. went through all this before, in the "post-Sputnik era" of the late 1950s and 1960s, yet here it is again. Or did it ever really go away?

One can argue about that, probably to little avail. However, any "friend of science," regardless of political or educational philosophy, can only be dismayed by the present overall state of science and mathematics education in U.S. elementary, intermediate, and high schools.

For one thing, students are taking fewer courses in mathematics and science than they did formerly. At the NAS convocation, Paul DeHart Hurd, professor of education (emeritus) at Stanford University, presented statistics, gleaned from a variety of sources, to make that point. Currently, for example, only 34% of U.S. high school graduates have completed three years of mathemat-

Most states are short on high school chemistry teachers



Source: 1981 survey, Science Education Center, University of Iowa

ics; of those, only 8% have taken calculus, which is taught in only 31% of U.S. high schools. Fewer than 20% of the graduates have had three years of science. Most seniors have had a course in biology and 37% have had chemistry, but only 19% have had physics.

For students pursuing academic courses—about 40% of the total—the numbers are, not surprisingly, higher: 55% have had three or more years of math and 41% have had three or more years of science. But of the other 60% who pursue general or vocational curricula, only 20% have had three years of math and hardly 10% have had three years of science.

Another study reveals that about 48% of U.S. high school students were enrolled in at least one science class in the school year 1976–77. In contrast, the figure was 59% (the highest ever) in 1960–61.

One problem with educational statistics is that there are a lot of them, and they don't always agree. Although the cited surveys describe high school math education, others suggest that high school students are again taking more math. For example, according to the National Center for Educational Statistics, the mean number of semester hours of math taken by high school seniors increased from 3.6 in 1972 to 4.1 in 1980, a 14% increase.

The Conference Board of the Mathematical Sciences notes that from 1975 to 1980 college-level math enrollments increased 33%, even as total enrollments grew only 7%. The board attributes some of that increase to the greater number of engineering and computer science students. However, much of the growth can be accounted for by remedial math courses, in which enrollments increased 70% in the 1975–80 period.

Some observers say that the quality of high school science and math education also has declined. For example, much is made of the fact that mean scores in mathematics on the Scholastic Achievement Test (SAT) declined from 502 in 1963 to 466 in 1980. Between 1967 and 1975, the proportion of students scoring more than 700 points (out of a possible 800) on the SAT math test dropped 15%; the proportion scoring fewer than 300 points increased 38%. Also, national assessments of science achievement—made in 1969–70, 1972–73, and 1976–77 and dealing with nine-, 13-, and 17-year-old students—showed continuing declines, especially for the 17-year-olds and for the physical sciences.

What such measures really say about the "quality" of science and math education is debatable. If fewer students receive instruction in science and math, it seems only natural that across-the-board test scores will go down. Although mean scores are declining, the "top" students seem to be getting better. Between 1969 and 1979, the number taking advanced placement examinations more than doubled, and mean grades moved upward steadily.

Whether more students should take more science and math is a value judgment. To most scientists and mathematicians, and to those that fear incipient scientific illiteracy of the masses, the answer is obvious: They should. That view isn't held universally, however. Unless the entire U.S. education system were made over radically, more science and math would mean less of something else. Other educational constituencies will defend their territories vigorously, and science/math proponents are underrepresented among the people who make educational decisions for elementary and secondary schools. A good "selling job" by these science/math proponents will be essential to gain more ground.

Although there's room for debate about how much science/math education is enough, or about how good it should be, there's hardly any argument that the science and mathematics substructures of U.S. elementary and secondary education are crumbling. Sarah E. Klein, an eighth-grade general science teacher and the retiring president of the National Science Teachers Association (NSTA), described the situation in recent testimony to the science, mathematics, and technology subcommittee of the National Commission on Excellence in Education.

Klein cited, for example, a 1981 survey of state science supervisors by Trevor G. Howe and Jack A. Gerlovich of the University of Iowa's Science Education Center. That survey, based on response from 43 states, disclosed a "critical shortage" of chemistry teachers in 10 states and a "shortage" in 27. For physics and math teachers, the situation was even worse. And for most other sciences, supply and demand were more or less in balance, at least in body-count terms, although there was a slight surplus of biology teachers.

Also, NSTA surveyed colleges and universities with teacher training programs. The results, Klein says, were "shocking." In 1971, the average such institution turned out about 22.5 new math teachers and 18.5 new science teachers. By 1980, the figures had dropped to about 4.9 math teachers and 6.5 science teachers—declines of about 78% and 64%, respectively. And, although numbers are lacking, it's reasonable to assume that many of the graduates didn't end up in teaching jobs.

Another NSTA survey, of secondary school principals, indicated that more than half the newly employed science and math teachers were unqualified to teach their subjects, at least according to the laws and regulations that spell out qualifications. They had been hired on an emergency basis because no qualified teachers could be found.

The same survey showed that in 1981 five times as many science and math teachers left the schools to take nonteaching jobs than left to retire. It also showed that the average science/math teacher was 41, with an average teaching experience of 16 years. Thus, the numbers suggest that high school science and math teachers are an aging group.

As to the quality of science and math education, other numbers give some hints. According to Klein, 60% of the science teachers face cuts in budgets for supplies and equipment, even though laboratory facilities already are obsolete. About 40% of the teachers never have attended a course or workshop since they began teaching. Among elementary school teachers, 51% say their undergraduate training gave them no preparation to teach science, 71% have never had in-service training in science, and 64% had no science consultants assigned to their schools.

How did U.S. precollege science education get in such a fix? It's popular, if not necessarily accurate, to blame most of the problem on the federal government and, in particular, the National Science Foundation (NSF). According to NSTA's Klein, for example, "There is, among those in the Administration, and among many others, the mistaken belief that science education has received substantial support, especially in recent years, and that since we now see all these serious problems, the infusion of massive federal support has been a failure."

Instead, Klein contends, "NSF support for science and engineering education has been declining steadily and steeply for the past 22 years." Science education's share of the total NSF budget dropped from a high of 47% in 1959 to a current low of 2%. Support for precollege science edu-

International comparison: how appropriate?

In the course of discussions about how much and what kind of science and mathematics education American students should receive, comparisons frequently are made between the way it's done in the U.S. and the way it's done in other countries (C&EN, Jan. 25, page 42). Comparisons of the U.S. system with the systems in such countries as the U.S.S.R., East Germany, China, and Japan seem to be particularly frequent.

Here, with no attempts at attribution or confirmation, is a representative sampling of recent pronouncements along that line:

- The school year averages 240 days; little time is lost in absences. The U.S. average is 180 days, with an average of 20 absences per student. The school week is five and a half or six days; in the U.S., almost uniformly five. The school day is six to eight hours; in the U.S., four or five. School vacations are short and dispersed through the year, to minimize interfering with the learning sequence. In the U.S., students take a three-month intellectual vacation every summer.
- Instruction in science and mathematics begins in primary school. Specially trained science and math teachers take over these subjects beginning in the fourth grade. Specialized study begins in the sixth grade. Biology, chemistry, physics, and earth science are required of all students, as are a full complement of math courses. Students spend three times as many classroom hours on these subjects as do U.S. students electing four years each of science and math.
- Students take three or four science courses each term, continuing over several years. This makes it possible to match subject matter to maturity levels and also promotes integrative activities between disciplines. General U.S. practice is to present scientific disciplines in discrete packages.
- Despite the emphasis on science and math, there's no slighting of social studies, the humanities, or foreign languages. Students take nine or 10 courses a year.
- English is regarded as the language of science. Currently there are more students and adults learning English in China than there are English-speaking people in the U.S.
- There seems to be none of the fear of science and mathematics among Japanese school children that is often found, particularly in girls, in the U.S.
- In the U.S.S.R., children study geometry for 10 years, compared with a one-year course, if that, in the U.S.
- In the communist countries test results are not interpreted in a competitive sense as to who has done well or poorly, but rather whether a student has mastered the prescribed subject matter. If test results are below expectancy, the student is tutored by the teacher and other students. The objective is to avoid failure.
- One striking difference between Soviet science education and that in the U.S. is the scientific credentials of people who prepare the curriculum that is used. Several internationally renowned research scientists and mathematicians spend a significant part of their time preparing textbooks for elementary and secondary schools.
- In these countries there is more parental concern, involvement, and responsibility for children's learning than is apparent in the majority of American families.

Enough already. Certainly the U.S. can learn from other countries. And anyone who has spent a day in a U.S. public school can testify that a fair amount of loafing goes on there. Nevertheless, statements like the above, delivered to buttress an argument, invite a certain amount of skepticism. They should be viewed in the same light as recent pronouncements of freedom of religion in the U.S.S.R. It's likely that, in those countries as here, the reality doesn't measure up to the ideal.

Is it merely coincidence that the favorite countries for such comparisons are countries with totalitarian governments or, as in the case of Japan, a nominally democratic government but with a long national tradition of conformity and submission to authority? Maybe not. Those are traits greatly admired in students by many educators. However, they aren't necessarily the traditions that made this nation great.

cation dropped even more sharply, from 72% of the science education budget in 1959 to 22% in 1980. "In terms of the total NSF budget, the precollege share has dropped from 34% in 1959 to its present low of less than 1%."

Much of the decrease in NSF support of science education has resulted from criticisms of curriculum development activities, Klein says. According to the critics, the "new" curricula purged application, concentrated heavily on pure science, and appealed mainly to the brightest students. Similar complaints have been made about "new math" programs. The new programs were "too hard," and thus contributed to the reductions in numbers of students taking science and math courses.

According to Klein, however, a recent NSF study suggests that "the new curricula were far more successful than most people realized." That study, which analyzed 105 other studies involving 45,000 students, compared students enrolled in new science curricula with students enrolled in more traditional programs.

"On every kind of measure, including achievement, attitude, and process skills, students taking the new NSF curricula scored overall 13% higher," Klein says. In the cases of the "BSCS Biology" and "Chem Study" curricula, scores were more than 17% higher. "What is most significant," she adds, "is the fact that students from low socioeconomic groups scored 24% higher using new NSF-supported curricula than traditional curricula."

Klein notes that those studies covered a period of several years in the 1960s and 1970s. Now, she says, few teachers qualified to teach such curricula remain in the schools, "and essentially none have been given the in-service training to do so since NSF abandoned that kind of program several years ago." And by now, Klein adds, "the materials are badly in need of revision and modification to take into account computers, modern electronics, and applications to technology."

Although NSF has taken a lot of flak about its current lack of support of precollege education, the fact remains that it must make do with what it gets from Congress. The agency has responsibilities in many areas of science, of which precollege education is only one. It must set priorities. It certainly isn't solely responsible for precollege science education in the U.S. By cutting off its precollege support almost completely—by bringing the matter to a head, so to speak—NSF rather dramatically has focused attention on a serious national problem. The foundation may have done the country a useful service thereby.

It's also popular to blame the reputed debacle in precollege science education on the science teachers

themselves. No doubt they deserve part of the blame. Science teachers, like their students, are a mixed lot: some wonderful, some terrible, most somewhere in the middle. On the whole, however, science teachers are victims of a bum rap, according to Robert B. Sigda. Sigda is an earth science teacher at a suburban junior high school. He also is the president-elect of NSTA. He also was, as he put it, the "token" precollege science teacher at the recent NAS convocation.

In his remarks to the NAS group, Sigda noted that successful learning ultimately depends on the classroom teacher. But the teacher can't do it alone. "Successful science teaching today is a complex interaction of student and teacher involvements with the program, classroom, home, and the national community," he says.

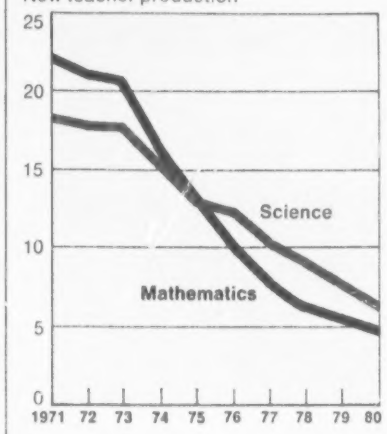
Currently, Sigda goes on, science teachers are facing an identity crisis. "Constantly under attack and blamed for all the nation's ills, teachers, especially science teachers, need a tremendous revitalization of spirit. The attacks are demoralizing to teachers who are trying hard to do a good professional job." When the teachers try to defend themselves against these attacks, Sigda adds, they are accused of being "defensive."

"With the present explosion of scientific knowledge and technology, one would expect science teachers to be filled with enthusiasm," Sigda says. Instead, they are deeply frustrated, because they are criticized constantly for a situation they have no power to cure. "They have the prescription but not the medicine."

Much of the problem is, of course, caused by lack of funds. "Herein lies the ultimate frustration," Sigda says. "The recent suggestions by some that all the funding for science education must come from the local level is totally unrealistic to science teachers who, for many years, have been trying to obtain money from these sources. Anyone familiar with the problems and pressures on local school boards knows that little, if any, funding will come from this source."

The answer isn't simply more federal money, however. In addition, "attitudinal assistance on the national level is needed if our nation's science programs are again to attain the position of eminence they once held," Sigda says. Probably most demoralizing to science teachers in that respect, he adds, is "the constant comparison made between science education in this country and science education in countries such as Japan and the U.S.S.R. It is the science teacher who is criticized when these other countries report that every student in their schools takes chemistry and physics, whereas in this country only 37% of the students take chemistry and fewer than 20% take physics. The major difference between the two systems is rarely reported, however. In the U.S., students *elect* science courses; in those other countries, students are *required* to take science courses."

Output of new teachers fell sharply during the 1970s



[a] Average numbers (per institution) of secondary school science and mathematics teachers produced in teacher training programs at U.S. colleges and universities. **Source:** 1981 survey, National Science Teachers Association

Sigda's prescription for that particular condition is for the U.S. to follow the example of the authoritarian nations: "The only sure long-term solution to the problem is for the states, who set requirements, to make science education mandatory for every student in this country, from kindergarten through 12th grade."

It might not be that simple. Making something mandatory doesn't mean that it will happen, or that results will measure up to expectations. Reading, writing, and mathematics are mandatory in the U.S. primary education system. But, as is well known, these schools continue to turn out sizable numbers of students who, for all practical purposes, can't read, can't write, and can't do sums. Would it be different with science?

Be that as it may, it's likely true that the main reason students don't take more science and math is that they don't have to. On the whole, requirements for high school graduation were eased during the 1970s, as were requirements for admission to colleges and universities. Students perceive, correctly, that science and math courses are harder than some of the alternatives. In the absence of coercion or convincing motivation, many of them simply take the easier way out.

Stanford's Hurd comments, however, that enrollments in school subjects are influenced by students' attitudes as well as by course requirements. Studies have shown that students don't particularly like science courses, he says, and that the dislike is acquired early. By the end of the third grade, according to one study, nearly half the students feel that they wouldn't like to take science (one can wonder how they arrived at that feeling, since, typically, minimal attention is devoted to science in early elementary school). By the eighth grade, only 21% of the students have positive attitudes toward science. That percentage remains about the same through high school. Another study shows that math popularity drops from a high of 48% in the third grade to a low of 18% in the 12th grade.

An encouraging note, Hurd adds, is that most students seem to like science when they learn it outside school—on television, or at museums and planetariums. But in the case of formal science courses, a majority of high school students feel that they are boring, with too many unfamiliar terms and too much emphasis on memorization of apparently unrelated facts, and generally irrelevant to everyday life. Obviously, a sizable minority of students don't feel that way. And "fun" is not a major goal of education. Still, the number of disaffected students is so large that their criticisms of science education oughtn't be dismissed lightly.

On the other hand, science education also may be plagued by too much relevance. When a national problem catches the public's attention, there's often a call to solve it by adding a unit to the science curriculum. "If it's found that young people are eating the wrong foods," NSTA's Sigda says, "a cry is heard for nutrition units to be added on to the science curriculum. Similar calls have been made for units in the areas of drug, alcohol, and sex education, as well as conservation, energy, environmental, and computer education."

Certainly, those are important topics. However, Sigda says, "If more time is to be spent on these issues, then science courses should be rede-

signed to reflect the addition of this 'new' information and the deletion of other information. Instead, the teacher is usually left to cope with the constant fracturing and disintegration of the science program." Despite all this adding on, Sigda adds, the public's expectation of science education never lessens.

The point is well taken: In that situation, something is bound to suffer. However, if Sigda had his way the kindergarten teacher similarly would be forced to add on a science unit to the kindergarten curriculum. What should be cut? Finger painting? Nap time? Milk break? The decision could prove difficult.

There's a current and growing shortage of precollege science and math teachers—especially of good ones—for much the same reason that fewer high school students are taking chemistry and calculus: Incentive is lacking.

For one thing, the current crop of college students has heard and heeded 1970s predictions of a teacher glut, and fewer are studying to be teachers of any kind. In fact, there is a surplus of people with certain teaching skills, but that hasn't been and isn't now the case for math teachers or for teachers of most sciences. Nevertheless, a lot of good students who could be good science and math teachers are deciding they'd rather be something else for some pretty good reasons.

Why, for instance, should a gifted college chemistry student aim for what is likely to be a dead-end job teaching high school chemistry, in which he or she will spend a good part of the workday doing things like filling out reports and keeping order in the halls, and in which he or she will have to put up with snotty adolescents, bureaucratic administrators, ill-equipped laboratories, and unreasonable expectations—all for $10,000 to $15,000 a year—when, with the same talent and essentially the same amount of effort, that gifted chemistry student could just as easily take a job in industry or government that would pay twice as much and also would offer more chance for advancement, better working conditions, and more respect?

Well, there are reasons, both noble and petty. The long summer vacations are nice. For people who just can't tear themselves away from their home towns, or for husbands or wives who have deferred to their spouses' careers, such teaching jobs may be the best available fulfillment of their own scientific ambitions. And, although

Klein: shocking drop in teachers

there is a tendency for the public to badmouth teacherdom in general, worthy individual teachers are, in fact, usually accorded considerable respect and status, especially in smaller towns where they are visible members of the community.

More important, there are still men and women for whom there can be no greater success than the successes sometimes achieved in guiding young people toward enlightenment. There are still people who, as the saying goes, "love to work with kids."

Fortunately, some of these people are also competent chemists—or biologists, or mathematicians, or whatever—so there always will be

Sigda: victims of a bum rap

some good high school science and math teachers. Unfortunately, there won't be nearly enough of them unless things change.

The choice of any career is determined by a number of factors, including abilities, connections, opportunities, desires, and dumb luck. In addition, any career must offer rewards (or no one would choose it) and it certainly will demand sacrifices of one sort or another. Individual perceptions of reward and sacrifice vary, but only within limits. Today, it seems, more and more of the people who would make good science or math teachers have concluded that the rewards of such careers can't compensate for the sacrifices. The teaching jobs probably will be filled by somebody. But they are more likely to be filled by the desperate than by the dedicated.

Another factor also may have contributed to the decline in numbers of new science and math teachers: the way the U.S. goes about training them.

In the last half of the 19th century and well beyond the end of World War II, the "normal school" and the "teachers' college" played large roles in U.S. higher education. The goal of these institutions was unambiguous: to educate their students broadly and to train them to be teachers in elementary and secondary schools. Their programs reflected that goal. What their graduates may have lacked in elegance, they made up for in serviceability, and they generally served the country well.

However, utility, like familiarity, often breeds contempt, especially in the academic world. Prestige and grants accrued not to the plebeian teachers' colleges but to the big state universities and to other glamorous research-oriented institutions. So in reactions to this and to an over supply of teachers, teacher training institutions have changed their names and expanded their goals.

In the mythical state of Sorry, for example, what used to be Possum Knob Normal School is now Sorry State University at Possum Knob. SSU at PK pretends it's just like the real Sorry State, only somewhere else.

Whether this development is on balance good or bad is, again, a value judgment. Times change and so do the U.S.'s educational needs. The rechristened schools are, on the whole, better than they used to be. The catch is that hardly any schools now have as their major aim the production of teachers.

Responsibility for production of elementary school teachers and for training of school administrators is assigned fairly clearly to university departments of education. But the responsibility for training teachers to teach specific disciplines in elementary or secondary schools has been left sort of floating around.

With respect to science and math teachers, Stanford's Hurd states the case this way: "The academic preparation of mathematics and science teachers has become an unrecognized responsibility of these departments in colleges and universities. These departments typically do not offer or require the range of background courses needed by teachers to qualify them for teaching nonspecialists. Some of these courses, for example, might be the sociology of modern science, statistical procedures in the behavioral sciences, human ecology, technology achievements, decision making, and general courses which provide a perspective of entire disciplines.

"In terms of professional qualifications," Hurd continues, "science teaching and engineering occupy the same position relative to science. Both are applied fields. Engineers select information from the sciences and mathematics to solve problems. Teachers select information from these same fields to interpret science to nonspecialists."

But, Hurd says, the education that a science teacher now gets "is that of a researcher cut short at the end of four years." Today, Hurd contends, "the training of science and math teachers in universities has become nobody's business."

Or maybe too may people's business, which can amount to the same thing. J. Dudley Herron, chemist and professor of science education at Purdue University, comments that "in Indiana, we have one school of medicine, two schools of engineering, one school of agriculture, and more than 20 schools which sometimes graduate chemistry teachers. Does this really make any sense? I don't think so. The number of medical doctors in Indiana is certainly more than the number of chemistry teachers." Herron is talking about Indiana, of course, but the point of his comment probably is valid for other states as well, and for other scientific disciplines.

Given the modest numbers of new chemistry teachers needed each year, it should be evident that special programs for chemistry teachers can be justified only if the necessary people and resources are concentrated in one or two places in each state, Herron says.

It's been suggested that Herron is in effect arguing for the return of the old normal school. Not so, he counters. Rather, "I would like to see the education of high school chemistry teachers carried out at a major university with a strong research program in chemistry as well as strong credentials in education. Both are needed to provide the expertise and the experiences needed for quality preparation of teachers.

"That institution should be adequately funded to carry out a program of excellence. It should recruit staff who are recognized for their excellence in teaching chemistry. Some of the faculty should be actively engaged in scholarship which is related directly to science teaching. Information gained from this research should be applied in courses for prospective teachers.

"For years we have argued that successful teacher education requires cooperation between professional educators and academic specialists," Herron continues. "But what happens in fact? In fact, it is difficult to get members of the chemistry faculty to sit on the Teacher Education Council. When I chair the Chemistry Certification Committee, other members accept my judgment on virtually every decision and rely on me to provide information and to initiate changes in our program."

Is that because Purdue chemistry professors don't care about chemistry teacher preparation? No, Herron says, it's because Purdue has fewer than 10 people graduating in chemistry education each year, compared to hundreds of agriculture majors, hundreds of engineers, and hundreds of students from other fields who also are taking chemistry.

"It's not callousness but realism that makes a physical chemistry professor more concerned about the 100 engineers in his course than about the four teaching majors," Herron says. It's not lack of concern, but self-preservation, that makes a faculty member prefer taking on undergraduate research students to designing a directed study for a teaching major. "There just isn't any percentage in devoting a large fraction of one's time to the few teaching majors rather than to the many majors in other professional areas," he says.

Nor do things improve after graduation. "A high school chemistry teacher needs graduate courses in chemistry to keep up with developments in the discipline—and to move up the salary schedule," Herron says. Teachers seek such courses during summer vacations. However, college chemistry professors move up their salary schedules "through scholarly achievement in the form of research publications or textbook writing. They try to do that during the summer. What high school teachers need for their advancement and what professors need to be doing for their advancement don't coincide."

Thus, at both undergraduate and graduate levels, the typical university chemistry curriculum ill meets the particular needs of the future chemistry teacher, according to Herron.

When chemistry is taught to future research chemists or is taught as a service course for students entering other technical fields, the primary need, the Purdue chemist-educator says, is to convey the principles of chemistry to them and to help them develop technical skills in applying those principles to problems in their fields. For those students, such things as seeing the applications of the principles to other fields and understanding the experimental evidence from which the principles were derived may be nice to know, but they aren't vital.

That isn't true for high school chemistry teachers, Herron says. Certainly they need to know the principles. But that isn't enough. Chemistry teachers need to know not only what chemists believe about matter but also why they believe it. They need a qualitative understanding of the principles, to be able to show students how a principle applies to a large number of situations in many fields.

Furthermore, it takes more than traditional chemistry courses and traditional education courses to make good chemistry teachers, Herron says. "Although prospective chemistry teachers will surely take education courses in which they will study the general principles of teaching, how those principles can best be applied to the teaching of chemistry isn't self-evident. Prospective teachers need to be exposed to *chemistry* courses in which strategies for developing an understanding of a principle are discussed along with the principle itself." Such courses won't be forthcoming, Herron concludes, unless enough students can be concentrated in one place to justify offering them.

Fortunately, the story can end with a cautiously optimistic note. There are signs that the situation has "bot-

Embassy of Japan photo

Elementary school pupils in Japan conduct experiment on oxygen properties

tomed out" and that the outlook for the future of science and math education in the U.S. is brighter than its recent past.

At the NAS convocation, for example, B. Frank Brown, chairman of the Florida Governor's Commission on Secondary Schools, said that "the state picture, which has been dismal, is now at a turning point. There is new momentum building among the states for increasing competence in science and mathematics. California and Florida, which led the trend to abandon graduation standards, now are leading in the other direction by proposing the enactment of new levels of excellence for graduation from high school."

Brown notes that another Brown, Gov. Edmund G., Jr., of California, in a recent "education initiative," has proposed that local school boards require at least three years of math and two years of science for all students, and more for college-bound students. The Florida commission goes even further, recommending requirements of four years each of science and mathematics for graduation from high school. Similar actions are at least in the planning stages in several other states. Many colleges and universities also are re-examining their entrance criteria, and the trend is toward stiffer science and math requirements.

Although organized teacherdom has a long record of being generally opposed to different pay for different subjects, market forces nevertheless are beginning to have an effect. For example, the Houston Independent School District has instituted a plan that provides for incentive pay to teachers in several categories, including the category "critical staff shortage." In the case of secondary science and math teachers, the stipend comes to $800 yearly.

The Houston plan also provides $400 stipends for professional growth, that is, for taking appropriate courses. Interestingly, courses in general education, administration, counseling, and guidance don't qualify; chemistry courses do. Stipends also may be granted for outstanding performance to teachers whose students do better than achievement goals would predict.

The stipends aren't very large, but every little bit helps. In any case, they're an encouraging sign of change in a field where merit traditionally has run a distant second to seniority.

The argument about the proper federal role in support of U.S. education continues to be noisy and the outcome uncertain. Still, even the most ardent of the "new federalists" seem to admit that the national government can't ignore the problems, and some new federal initiatives are pending.

For example, Sen. John Glenn (D.-Ohio) and Rep. Don Fuqua (D.-Fla.) recently introduced parallel bills in their respective houses that would establish, within NSF, a National Coordinating Council on Engineering & Scientific Manpower. One purpose of the council would be to encourage and promote high-quality precollege science and math education. The bill would set up a fund, initially $50 million a year, to carry out the council's charge.

Also, Sen. Gary Hart (D.-Colo.) and Rep. Carl D. Perkins (D.-Ky.) have introduced bills that would lead to an "American Defense Education Act," with such objectives as increasing national productivity and strengthening national security. These bills include provisions for monetary incentives for local school districts to improve elementary and secondary education in the sciences and mathematics as well as in foreign languages, communications skills, and new technologies.

All these bills are still in early stages of gestation. It's too soon to know what their final form will be, or whether they will pass.

Federal educational assistance programs have been accused of lacking focus and direction. The current Administration denies that it's turning its back on U.S. education problems; rather, it has deliberately suspended what President Reagan calls "a proliferation of small federal programs which—taken together—showed themselves to be ineffective."

To try to provide some focus and direction, the National Science Board (NSF's policy-making body) last year established a Commission on Precollege Education in Science, Mathematics & Technology. The commission, comprising, according to NSF, "18 highly respected individuals from a wide variety of fields," started work in April. Its job, to be done by Oct. 15, 1983, is "to define a national agenda" for improving science and math education and to "develop an action plan that will include a definition of the appropriate roles of federal, state, and local governments, professional and scientific societies, and the private sector in addressing this problem of national dimension."

As noted, many of those entities already have begun to take action without waiting for their roles to be defined.

For example, the American Chemical Society. It probably isn't grossly unfair to say that for a long time the main service that ACS rendered to high school chemistry teachers was lip service. That situation has changed markedly in the past few years, however.

The ACS Division of Chemical Education formed a High School Chemistry Committee in 1978 and gave it the job of "bringing high school chemistry teachers into the mainstream of chemical education activities." The following year, the Office of High School Chemistry was established within the ACS Department of Educational Activities. The two work closely with each other and with ACS local sections.

Only about 37% of high school students choose the chemistry option (here being taught by Claire Smith at a San Francisco high school)

Also within ACS, regional, national, and divisional meetings and conferences have been broadened to include programs specifically aimed at secondary level teachers. The *Journal of Chemical Education* for the past several years has had a section devoted to secondary chemical education articles.

At the local and regional levels, "Expert Demonstrator Training Activity" workshops have been developed to train local section members to perform effective chemical demonstrations and to conduct their own workshops for local high school chemistry teachers.

The ACS Office of High School Chemistry publishes a quarterly newsletter, *Chemunity*, available free to interested high school teachers. It's published a booklet to help local sections organize effective programs to promote chemistry in high schools. It makes available a variety of teacher support and continuing education materials. It coordinates award programs for high school chemistry teachers.

Currently, the office also is coordinating the development of a new interdisciplinary science course for 10th grade students. This course, "Chemistry in the Community" (ChemCom), aims to use chemical concepts for "helping students to understand and to seek solutions for technology-related problems of today." The project is directed by chemical educator W. Thomas Lippincott of the University of Arizona.

ChemCom will consist of 10 modules, with titles such as "Supplying Our Water Needs," "Understanding Nuclear Issues," and "Chemistry in Public and Personal Health." NSF has furnished funds to develop seven of the modules and the ACS Petroleum Research Fund for an eighth module, "Petroleum: Uses, Resources, and Importance for Society." Funds for the other two modules still are being sought.

Other professional and scientific organizations, like the American Association for the Advancement of Science (AAAS), also are showing increased sensitivity to the needs and problems of the secondary school science and math teacher. AAAS, for example, has begun a Teacher Notes project "designed to help bridge the gap between what is happening in the sciences and what is taught in the schools." The notes include suggestions for student activities using easily available and inexpensive materials. Related slides, posters, and computer programs to back up the notes also are planned.

In another project, AAAS, with funds from Phillips Petroleum, will produce "Challenge of the Unknown," a set of supplementary math materials "to help teachers enliven mathematics learning" by students in the middle grades.

In the field of general educational research, considerable recent progress has been made in understanding basic mechanisms of learning—with obvious implications for the teaching of chemistry and other sciences. From some of this research have come suggestions that the way chemistry usually is taught today may have little relationship to the way it's learned (C&EN, April 12, page 35). Not everyone accepts all the findings of this research, but nevertheless it has led to a renewal of interest in research on science teaching as such.

In addition to efforts to improve the quality of science education, there also are efforts to make science more attractive to more students. Some of the ACS activities aimed at precollege students—like Career Days and "Meet a Scientist" nights—are frankly promotional as well as educational.

Also, a good many chemists around the U.S. have taken it upon themselves to present "chemical magic" shows—complete with color changes, chemiluminescence, clock reactions, and explosions—to younger students. At the University of Wisconsin, for instance, Bassam Z. Shakhashiri notes that he and his group have put on "Chemistry Can Be Fun" programs 18 times just this year, for some 5000 junior high students in the Madison area.

Another encouraging note comes from Chicago, where the Regenstein Foundation has donated $1 million to the Museum of Science & Industry for a permanent exhibit on "Everyday Chemistry." A highlight of the exhibit, which is set to open next June, will be a group of 14 chemical reactions and demonstrations, controlled by microprocessors but set in operation by the visitors. "You will note color changes and luminescence, identify organic compounds by smell, and feel the heat released from reactions," a museum spokeswoman notes.

Some chemists look askance at that sort of frivolity. "Chemistry isn't supposed to be fun," they say in effect. "Chemistry is hard work." Well, one can accept the second premise and still dispute the first. In the course of his duties, this reporter has interviewed many distinguished practitioners of chemistry, often in connection with their receipt of some prestigious award. A stock question on such occasions is ,"Why are you a chemist?" Perhaps the most frequent answer is, "Because it's fun." Not noble, or important, or beneficial to humanity, or intellectually challenging (though it may be all those things), but "fun."

The more chemists—and other scientists, and mathematicians—bring themselves to unhypocritical acceptance of that notion, the more successful they will be in winning young students to their cause. □

Industrial gases fighting excess capacity

As the recession bites into demand for oxygen, nitrogen, and carbon dioxide, plant construction continues, worrying some producers

William J. Storck
C&EN, New York

In some ways, 1982 is shaping up as a repeat of 1981 for industrial gas producers, but perhaps worse.

Production of the largest-volume gases is, in most cases, off from last year's levels. Prices are not rising to keep up with cost increases, and many of the announced price increases have not stuck. Some producers seem to be trying to grab market share at the cost of profitability. And excess capacity is overhanging the entire market.

In the first quarter of this year, capacity utilization for industrial gases was running at an average of about 64%, down considerably from 69% in the third quarter last year and about 66% in the first quarter a year ago.

Producers say that profitability is still below reinvestment levels, especially considering the high interest rates that go along with financing new plants.

But, they keep on building. Most producers say they have not cut back on capital plans, but rather are "building for the future." And, they say, many of the new plants will replace older facilities.

Some producers, however, are beginning to become concerned. They say that if the current wave of building continues, there are going to be a lot of shut-down plants—especially air separation facilities for oxygen and nitrogen—in the industry. The situation does not seem to be so bad for carbon dioxide, plants for which are limited by the amount of feedstocks that can be derived as a by-product from other chemical processes.

Key Chemicals

And to a certain extent, some plants are shut down right now. But most of the facilities that have been shut down permanently have been replaced by newer, more efficient units.

One of the reasons for building now may be a shift in the geographical nature of the business. Industrial gas producers say they are building more plants in the South and in the Pacific areas as their customers gravitate that way. And they are trying to build in areas where electrical power is less expensive.

Unfortunately, these two aims are operating at cross purposes to a certain extent. Although the industrial gas business in the Midwest is in poor shape because of the steel and auto industry slumps, this seems to be the area where producers can get cheaper electrical rates. And the Pacific has some of the highest electrical power rates in the country.

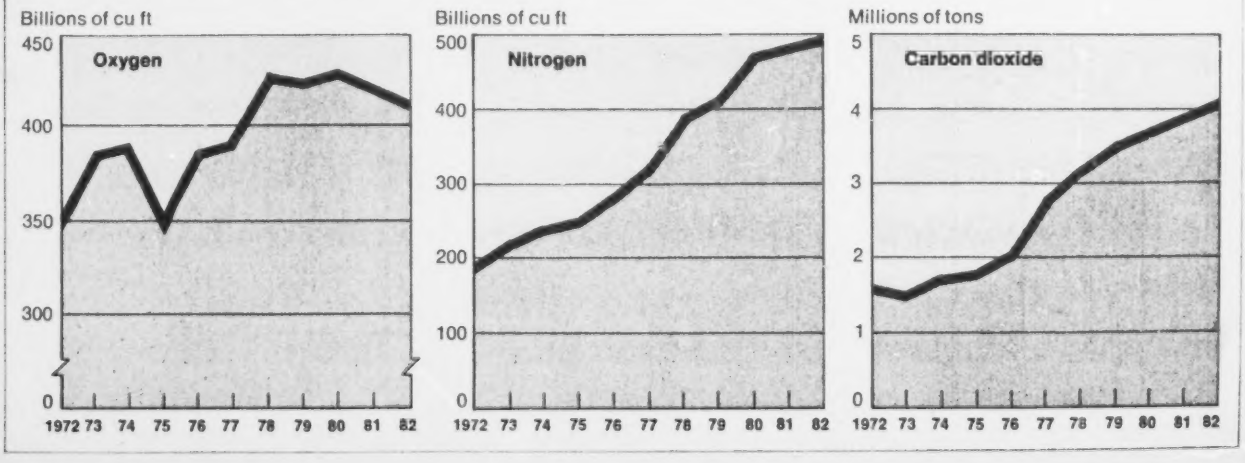
The recession is biting into the industrial gas business in terms of transportation as well as in pricing and demand.

Producers say that the costs of shipping in wages for drivers and for fuel is increasing, but not so fast as it has been in the past.

The recession has hit more than just the three largest-volume gases. Hydrogen also is having a hard time of it this year as its uses in chemical processing and blanketing atmospheres for metals decline. Producers say the hydrogen business is approaching maturity, and they also are finding that it is not so recessionproof as they once thought. Prices for hydrogen have increased only about 1% this year. And there will be only marginal growth, producers indicate. In fact, for the long term, hydrogen makers say that markets probably will grow only about the same as the gross national product.

For a more detailed 12-month outlook for nitrogen, oxygen, and carbon dioxide, see the following pages. □

Carbon dioxide, nitrogen output has grown steadily, but oxygen has slipped



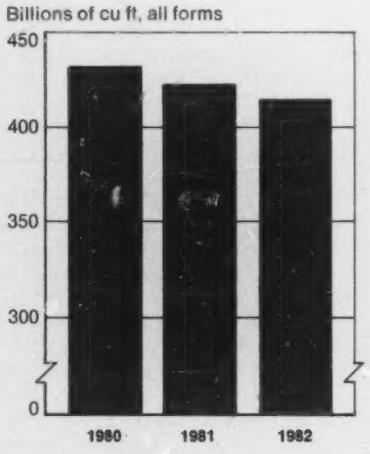
Key Chemicals

Oxygen

O_2

- ***Demand down***
- ***Prices soft***
- ***Margins slipping***

PRODUCTION



HOW MADE

Separated from air at low temperatures

MAJOR USES

Primary metal manufacturing 30%, health services 13%, metal fabricating 33%

FOREIGN TRADE

Negligible

PRICES

41 cents per 100 cu ft plus shipping and equipment charges (merchant)

COMMERCIAL VALUE

$470 million for production, 1982

Oxygen, which used to be the largest-volume industrial gas, has run into so many problems over the past few years that it has slipped to second place behind coproduct nitrogen.

In fact, the two gases exchanged places on C&EN's list of Top 50 chemical products last year, with oxygen falling to fifth place from third, and nitrogen rising to third place in 1981 from fifth place the year before.

It really is no surprise that oxygen has fallen on hard times. It is the most vulnerable of the industrial gases to fluctuations in the economy. Its biggest markets are in highly cyclical industrial markets such as steel and other commodity metals. Thus, when auto production declines, so does steel output and, consequently, demand for oxygen.

One producer says that so far the steel industry is performing almost abysmally. The producer adds that steel production is down about 34% thus far this year, after a pretty good first quarter. He estimates that for June and July, steel production may well be down as much as 50% from last year's levels.

This situation over the past couple of years has led oxygen into a classical recessionary situation with overcapacity on the production side and discounting on the price side.

Overcapacity is something that may well remain with oxygen producers not only through this year, but into 1983 and perhaps 1984 as well. One producer says that even with the current overcapacity, there seems to be very little cancellation of projects currently under construction and slated to come on stream both this year and next. However, new plants coming on stream are replacing some older plants that are not so efficient.

Efficiency of production and productivity are meaningful words to producers these days as energy costs, which are the primary production costs, continue to escalate. Producers note, however, that cost increases in energy have slowed from a year ago.

Still, producers are being squeezed in terms of profitability. Although production costs as well as transportation costs are not increasing so fast as they were, the price that producers are getting is not increasing so fast as costs.

Producers say that although they tried to get an 8 to 10% increase last September, they actually are getting about 1 to 2% more for merchant oxygen than they were getting at this time last year, mainly because of discounting. Two reasons are given for discounting. One is that market conditions are such that users of oxygen can stall any price increase. The second reason is that newer entrants into the industrial gas market are trying to compete on price rather than technology. Thus, they are discounting their product in an effort to gain market share. And, with the current—and probably continuing—overcapacity, producers say that pricing problems will be around for a while.

On the tonnage or pipeline side of the business, which is tied more closely to big steel than is merchant oxygen, producers say that, despite take-or-pay contracts, profitability is below reinvestment levels, especially considering current high interest rates.

Oxygen producers claim that for tonnage, as well as for merchant oxygen, the first quarter started out below year-before levels, but in the past few months demand has taken an even sharper turn downward. Through the first quarter, oxygen demand was off 8.8% from first-quarter 1981. April production, however, was down 15% from April 1981.

Producers think that May and June were off even more as steel production has dropped drastically and output of automobiles at the end of June hit its lowest level in more than 20 years.

For the remainder of the year, oxygen producers are not at all hopeful. They say that since practically all of oxygen's markets are down and since the major market is in metals, it will be at least 1983 before there can be any hope at all of a turnaround.

Given the current state of the market, producers may try for yet another price increase later in the year (something they have not done since last September). But, they may not have any more luck with one this year than they did last.

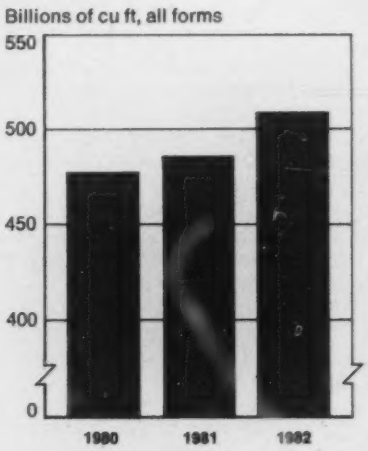
Thus, for the remainder of the year, it looks as if producers are going to continue to suffer the ills they have had for the past year—low capacity use, soft pricing, and increasing costs.

N_2

Nitrogen

- ***Growth slows***
- ***Prices discounted***
- ***Margins shrinking***

PRODUCTION



HOW MADE

Separated from air at low temperatures

MAJOR USES

Blanketing atmospheres—chemical processing 14%, electronics 16%, metals 5%; freezing agents 21%, aerospace 8%

FOREIGN TRADE

Negligible

PRICES

39 cents per 100 cu ft plus shipping and equipment charges

COMMERCIAL VALUE

$430 million for production, 1982

Nitrogen—long the number two industrial gas in terms of volume, but now number one—is not having a particularly good year, according to producers.

For the first four months of 1982, production has fallen to 159 billion cu ft, down 0.5% from the same period in 1981. Coming off only 1.3% growth between 1980 and 1981, this is bad news to nitrogen producers, who are used to bigger numbers than that.

For the past 10 years, according to U.S. government figures, nitrogen production has been growing at more than 11% per year and in 1980, production was up 16% from 1979.

So, in the current recession, what may look fairly good to producers of other large-volume chemicals looks pretty dismal to producers of a product that until just a year and a half ago was growing at a fairly constant high level.

Now that nitrogen has gained the top place among the industrial gases, it probably will stay there. Although it is not doing very well this year, nitrogen has more growth markets than does oxygen, which formerly held the number one slot. In addition, nitrogen's markets are much more diverse than those for oxygen, which is tied largely to commodity metals in one form or another.

Nitrogen, too, has some markets in metals, mainly as a blanketing atmosphere; producers say that demand in this area is down considerably this year. But use in some of its other markets is either up slightly or on hold with producers expecting renewed growth when a turnaround does come.

Food freezing is one market that producers say is performing fairly well this year. They claim that this market is largely countercyclical. During a recession, people either increase their use of frozen foods at home or eat more at fast food outlets, which use food frozen with nitrogen (or carbon dioxide).

Another area showing fairly good growth, although not so fast as in the past, is in oil field use. Producers say that in the past, nitrogen use for enhanced oil recovery had been growing so fast that they have had trouble tracking it. This has slowed considerably in the past year as oil demand has fallen, but they see a pickup in the future.

Oil field use of nitrogen is growing well for both the merchant and tonnage types. Merchant nitrogen (and oxygen) is that sold as gas or liquid in cylinders and tank cars. Tonnage industrial gases are produced at on-site plants and the gas is piped directly to the user.

In oil fields, merchant nitrogen is used under contract in pilot operations usually lasting from one to three years. If the use works out in enhanced recovery, an on-site plant will be built to provide much larger volumes more economically.

Nitrogen, however, is plagued with many of the same problems as other gases—rising costs and fairly flat prices, resulting in shrinking margins.

The cost of electricity, which is the primary production cost for nitrogen producers, has been escalating at more than 10% per year. In addition, labor costs and the cost of transportation have been increasing rapidly. These cost increases have been slowing somewhat this year, producers say, but not enough for the occasional price increases they have been getting to keep pace.

Nitrogen currently is selling to the largest merchant users at an average price of about 39 cents per 100 cu ft. This is up just 1 cent from this time last year, although producers tried to get an 8% increase last September.

And even the 39-cent price may be illusory. Producers say that the discounts on individual deals are such that it is practically impossible now to say what the real price for nitrogen is.

The rising costs—especially electricity—associated with nitrogen also may hurt the refrigeration use of the gas in the long run. Producers say that as the costs and, therefore, prices go up, many refrigeration users may begin to look at other methods such as mechanical refrigeration or carbon dioxide.

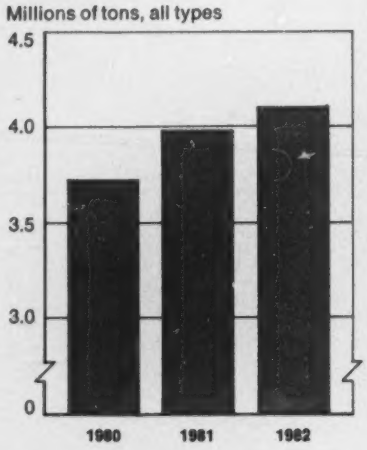
For the remainder of 1982, producers do not see that happening, however. What they do see is a moderate increase in demand for the remainder of the year so that nitrogen may finish 1982 with production about 4 to 5% ahead of 1981. Prices probably will go up later in the year, but whether producers will be able to get what they ask or whether it will be a repeat of 1981's much reduced actual price increase is still open to some question. Probably, it will be the latter as demand probably will not pick up enough to persuade users to pay the full price.

CO_2

Carbon dioxide

- ***Demand still up***
- ***Prices higher***
- ***Feedstock tight***

PRODUCTION



HOW MADE

Recovered from synthesis gas in ammonia production, recovered as by-product in substitute natural gas production, recovered from fermentation ethanol production, recovered from natural wells

MAJOR USES

Refrigeration—food 37%, industrial 5%; beverage carbonation 20%; other industrial uses 22%

FOREIGN TRADE

Negligible

PRICES

About $71 per ton for largest users; prices vary by region

COMMERCIAL VALUE

$147 million for production, 1982

Carbon dioxide is doing better this year than either of the other two large-volume industrial gases—nitrogen and oxygen—after performing better than either of them in 1981.

Last year, production of carbon dioxide grew 7% from 1980 to almost 4 million tons. In spite of that, however, it still fell from 18th to 19th place on C&EN's list of Top 50 chemical products.

For the first four months this year, production is running about 3.6% ahead of last year, according to the Bureau of the Census. Output in January through April was about 1.30 million tons, compared to about 1.25 million tons in the same period of 1981.

Output of liquid carbon dioxide, the largest-volume form, however, is down about 1.8% to 920,869 tons in the first four months. Solid carbon dioxide, or dry ice, output is also down, declining 10.7% to 90,709 tons in the first four months of the year. Producers expected this of dry ice, however; its output hasn't grown for a number of years.

The area that has made up for the rather lackluster performance in the other two forms is gaseous carbon dioxide, whose output through the January through April period is up 33.9% to 289,050 tons. Two reasons for its tremendous growth are: There are new customers for it who eventually will upgrade to liquid as their businesses grow, and there has been enough shrinkage of businesses that previously used liquid carbon dioxide that they have returned to the gaseous form. Most of the customers for gaseous carbon dioxide use small quantities of the gas.

The biggest problem that carbon dioxide producers seem to be having is acquiring the carbon dioxide to sell. Most carbon dioxide comes from ammonia plants, which are being hit by a slump in fertilizers. During the first quarter, ammonia plants were operating at about 80% of capacity (C&EN, May 24, page 16). However, this level may well have dropped since then. Carbon dioxide producers say there are plants shut down completely and others that are operating on a sporadic basis. At this time last year, carbon dioxide producers already were complaining about availability of supply, and this year, ammonia production through April was 16% below year-before levels.

Carbon dioxide producers seem to be doing better in pricing than are producers of other industrial gases. Prices of liquid carbon dioxide have increased to about $71 per ton for the largest users from about $64 per ton a year ago. This price varies greatly by region. And producers say that prices are not being discounted, as they are with oxygen and nitrogen, although there is some price cutting.

Food freezing still is the fastest-growing, large-volume use for carbon dioxide, and producers believe it may continue to grow for some time. They see many customers who presently use nitrogen in food freezing switching to carbon dioxide as the costs of producing nitrogen continue to increase. Nitrogen producers, however, say there will be just as much switching to mechanical freezing, if this is the case, as there will be to carbon dioxide.

In the past, both nitrogen and carbon dioxide producers claimed that certain foods freeze better with one or the other of the two gases. Now, however, they pretty much have abandoned that line and say that although some foods may require one or the other of the gases, these types of foods are very few. "Cost is now the major factor," says one carbon dioxide marketer.

The other fast-growing area for carbon dioxide—oil fields—also pits the gas in competition with nitrogen. In this area, producers say they are a little slower off the mark against nitrogen; "There seems to be a bias toward nitrogen which we are finding difficult to counter," one producer says.

For the rest of this year, carbon dioxide well may prove to be the best performer of the gases. Producers see demand for the product growing at about 5 to 6% this year. This is possible if demand holds up through the peak summer season and the oil field uses come back somewhat in the fall to take up the off-season production.

Prices are almost sure to increase later in the year, and although the announced increase may not be so great as for the other industrial gases, the actual increase may be higher if discounting in oxygen and nitrogen continues.

Gloom hangs over European chemical industry

Belgium's Jacques Solvay, immediate past president of the European Council of Chemical Manufacturers' Federations (CEFIC), struck a somber note when he addressed that group's annual general meeting in Basel last month. He doesn't see much likelihood of a pickup in chemical business in Western Europe this year, and he can only hope for some improvement in 1983.

Citing the situation for petrochemicals and commodity plastics, two areas of the industry that are hardest pressed, he notes that overcapacities are on the order of 40%. Competition is very stringent, he adds, and imports from eastern countries, among others, are coming in at very low prices.

Chemical production index data from West Germany and the U.K. lend credence to Solvay's views. In West Germany's case, the chemical production index averaged 144.7 (1970 = 100) between January and April, 5% less than the monthly average for the corresponding period last year and in 1980.

The U.K. fared better, with a January-through-April average index of 124.7 (1970 = 100), 2% more than in 1981. "It is encouraging to see some slight improvements in several sectors of the industry, albeit from a very low level," comments Martin Trowbridge, director general of the U.K.'s Chemical Industries Association. There hardly is room for complacency, however. The four-month average so far this year is more than 9% less than the corresponding average for 1980.

The chemical price indexes for this year's first four months were up in France, West Germany, and the U.K. Compared to the four-month average in 1981, France's prices gained 15% to an index of 329.8 (1970 = 100). West German and U.K. price indexes rose about 7% to 171.5 and 403.5, respectively.

Closer scrutiny of the price index data suggests a leveling off in the growth rate. At least this was the case through April. Compared with January, April's reading was just short of 4% higher in France, a mere 0.2% ahead in West Germany, and 1% up in the U.K. In 1981, the advance over the same time period was 6% for France, almost 5% for West Germany, and 2% for the U.K. In contrast to the meager rise in West Germany's wholesale chemicals price index during the opening months of the year, coal costs there have risen 11%, electricity 16%, and natural gas 30%.

The adverse economic climate is forcing many companies out of business. Chemical concerns haven't been immune. According to data just released by Dun & Bradstreet in the U.K., there were 86 company liquidations in the chemical industry in England and Wales alone during this year's first six months—39 in the first quarter, 47 in the second.

Depressing as this situation is, the number of liquidations is 6% less than in last year's first half. And it is less than 2% of total company liquidations in England and Wales so far this year.

Most chemical industry executives throughout Western Europe, nevertheless, hold that companies should take steps to overcome their problems on their own, rather than seek government aid.

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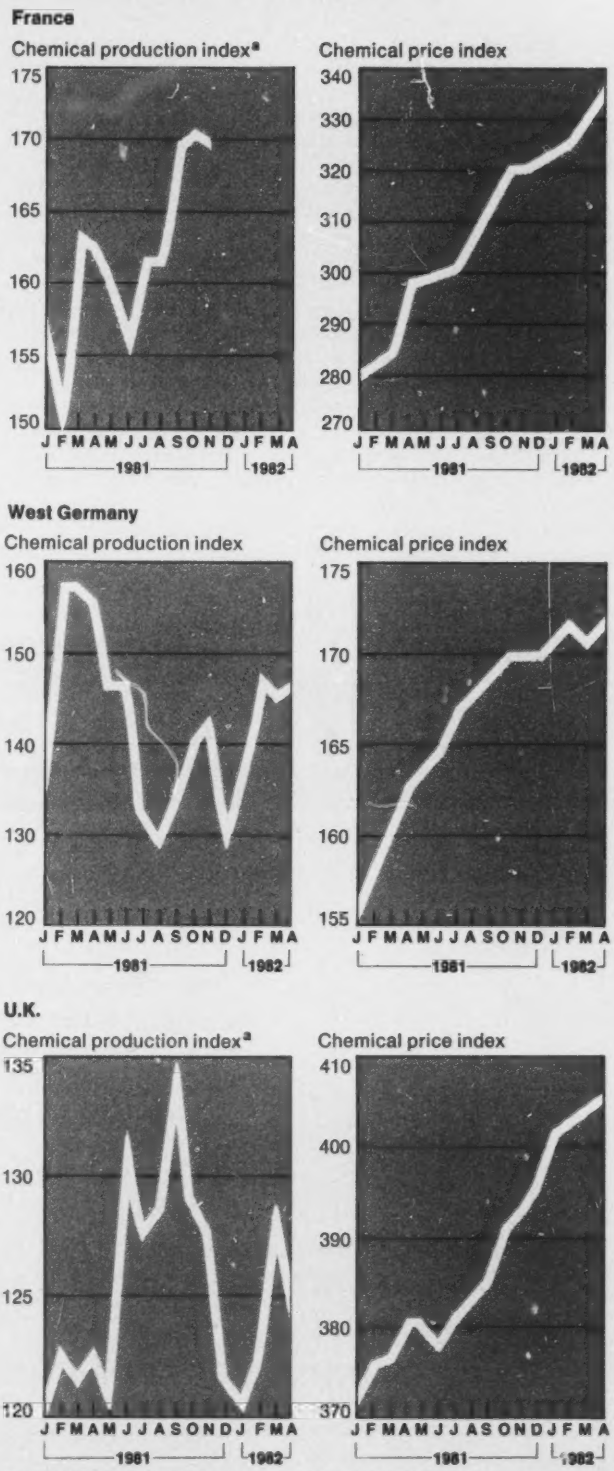


a Seasonally adjusted. **Note:** Base year for all indexes is 1970 = 100.

Methanol: Future fuel for electric utilities?

Electrical utilities seek independence from oil and gas suppliers by exploring ways to make their own fuel from synthesis gas

Joseph Haggin
C&EN, Chicago

Electric utility companies may wind up in the chemical business by default. The need for large quantities of clean liquid and gaseous fuels to power generating stations of the 21st century has presented the companies with a dilemma: Either continue to struggle with current financial and fuel supply difficulties or develop sources of fuels.

Development of fuel sources is being explored seriously by Electric Power Research Institute (EPRI). It now looks as though one of the most attractive alternatives is the captive production and consumption of large quantities of methanol from synthesis gas.

Driving the dilemma are a number of problems that provide strong incentives to companies for keeping existing generating plants on stream as long as possible, as well as for being quite deliberate in the acceptance of any new construction commitments—nuclear, conventional, or otherwise. These problems include severe capital shortages, escalating interest rates, and environmental constraints.

One specific problem is the amount of present generating capacity powered by oil and gas. About 200,000 MW of U.S. generating capacity is in this category, with much of the fuel being imported. Price hikes in imported fuels and in the utility rates paid by consumers have resulted in sharply reduced demand for new generating capacity in the future. They also have made the problem of satisfying off-peak power demands more acute.

Utility industry leaders continually complain about being at the mercy of oil and gas suppliers. And the prospect of a national synthetic fuels industry in the future doesn't hold many attractions for them because the synfuels producers probably will be current oil and gas producers. The net effect is a concerted effort by electric utility companies to achieve as much energy independence as possible.

Price escalations in imported fuels and progressive deregulation of domestic gas and oil have made a shambles of utility company economics. Thus, the desire for fuel with a secure supply and predictable price is too strong to resist any longer. Already firmly entrenched in the coal business, most of the larger utilities have turned to optimizing the use of coal, and one means is coproduction of gaseous fuels (medium-Btu levels) and fuel-grade methanol. This approach is particularly attractive for peaking generators, but it eventually may be the choice for baseload capacity as well.

Being an "ultraclean" liquid fuel, methanol has no trouble meeting the environmental requirements imposed by state and federal governments. It has no undesirable emissions and contributes no nitrogen oxides to stack exhausts. Methanol also burns at a lower temperature than most fuels derived from petroleum. This may or may not be an advantage, but it does make the design of methanol combustion units somewhat simpler.

Methanol and medium-Btu fuel gas are intended for use as turbine fuels either in dedicated electricity plants or in cogeneration plants, which also produce steam. So far, methanol never has been used in the U.S. as a turbine fuel, but in 1979 a 523-hour test by Southern California Edison consumed 2.5 million gal of methanol with excellent results. The biggest impediment to use of methanol at present is high price.

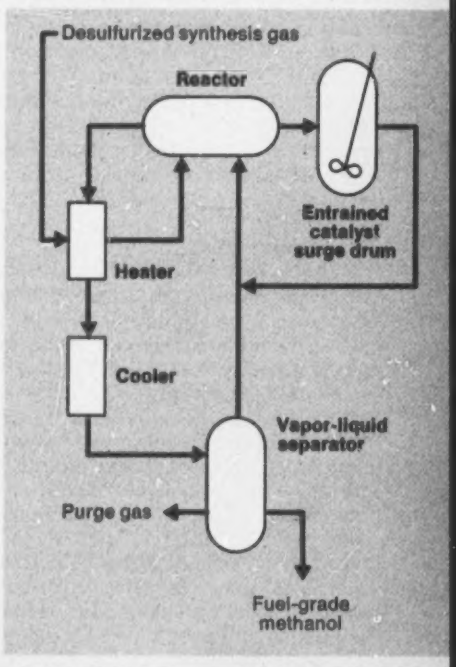
Although the conventional methanol market may be depressed, current production capacity would be insufficient to meet possible future demand for fuel-grade methanol. Most of the technology required to produce the large quantities of methanol needed for utility consumption is available. However, this technology also is intended for other purposes and would have to be adapted to the needs of utility companies.

EPRI has been examining the newer technology and appears to favor some of the second-generation gasifiers and some methanol processes that still are in the development stage. For example, the institute has been assisting development of the Texaco coal gasifier as well as Chem Systems' liquid-phase methanol process. Both of these processes now are being considered for inclusion in an integrated methanol plant to supply fuel for a cogeneration plant in southern California.

In the scenarios being developed by EPRI, two major types of plants are being considered. One is a very large baseload plant. The other is a highly flexible peaking plant, which must be capable of operating over a great range of capacity. The requirements for plants of both types are quite different from requirements for retrofitting existing plants, but both are operable with cogeneration in mind.

Intermediate-Btu fuel gas would be

Methanol process variation uses liquid-entrained catalyst reactor



Liquid-entrained catalyst reactor leads to lower methanol costs for liquid-phase process

Costs[a]	Liquid-fluidized reactor	Liquid-entrained reactor
Fixed capital, $ millions, 1980	**$60.0**	**$36.3**
Battery limits	50.0	30.3
Associated off-sites	10.0	6.0
Annual production cost, $ per ton methanol[b]	**9.5**	**2.4**
Catalyst	2.3	2.1
Utilities		
Steam	(11.2)	(11.6)
Boiler feed water	0.3	0.3
Cooling water	0.1	0.1
Power	0.4	0.6
Total	(10.8)	(10.5)
Capital-related expenses at 30%	18.0	10.8

a For 3000 tons per day of methanol in a once-through operation, with a synthesis gas feed of 817.7 million standard cu ft per day for the liquid-fluidized reactor and 511 scfd for the liquid-entrained reactor. b Excluding synthesis gas.
Source: Chem Systems

the fuel of choice for many units, but the variable demand would require some way to handle excess fuel gas during periods of low demand. One alternative is coproduction of methanol from the surplus fuel gas (synthesis gas). The methanol would be easier to store, is stable, and could be used as a clean turbine fuel as needed. That methanol is an eminently salable commodity also could offer some market leverage for potential producers.

In developing its alternative designs, EPRI has considered three major scenarios. One assumes a single-pass (no recycle) reactor that converts much of the synthesis gas from the gasifier. The most frequently cited example is the Chem Systems liquid-phase process, which converts about 25% of the feed synthesis gas to methanol in a single pass and does not require much feed pretreatment. This simplicity is desirable because it eliminates the capital costs required for recycle equipment, shift reactors to adjust composition, and other equipment.

A second possibility is to divert 30% of the synthesis gas to a methanol production unit, shifting the composition as required, removing the acid gas components, and sending the gas to a conventional process such as the ICI process or its equivalent. The remainder of the synthesis gas would be consumed directly by the generating plant. Varying amounts of the methanol then could be used to satisfy peaking demands.

A third alternative is a coal-based methanol plant in which all of the synthesis gas is converted to methanol using conventional technology.

Many variations of the three alternatives have been examined by EPRI and its consultants. The economic projections suggest that methanol coproduced by a utility company with the best available combination of processes (gasification and methanol synthesis) would cost about one third less than that purchased from a nonregulated company. Even with conventional (recycle) processes the savings could be as much as 20%.

In any case, utilities see the methanol option as a way to gain independence from other methanol producers and still offer a great deal of operating flexibility. If a utility company is contemplating construction of a new gasification/combined cycle generating plant based on coal, the net cost reduction of the liquid fuel could be as much as 40%, but much depends on local circumstances and future methanol markets.

One of the technical catches in all this is that much of the desirable technology on which the scenarios are built still is under development. Despite the availability of various gasifiers and very efficient methanol processes, the technical and economic attractiveness of the newer second-generation processes is a major incentive to speed development of these processes and to give serious consideration to bypassing the older technology.

A case in point is the combination of the Texaco coal gasification process, which evolved from a process for the partial oxidation of heavy crude oil fractions, and the Chem Systems liquid-phase methanol process, which is being developed in several variations. In July 1979, Texaco and Southern California Edison formed a group to build and operate a 1000-MW demonstration coal gasification/combined-cycle power plant at the utility's Cool Water station near Barstow, Calif. The plant is scheduled to begin operation in 1984 and will utilize the Texaco gasification process. EPRI has commissioned Fluor Corp. to evaluate the possibility of integrating a methanol facility into the Cool Water project based on the single-pass version of Chem Systems' methanol process. The goal is to determine the cost of by-product methanol from an operating plant.

One of the features of the Chem Systems process that is particularly appealing is its 68.8% conversion efficiency of coal to methanol in the single-pass version. In a conventional, dedicated methanol plant the corresponding efficiency is cited by EPRI to be usually less than 58%. The improvements in efficiency are explained by the lack of a requirement to shift the synthesis gas composition or to deacidify the synthesis gas before feeding it to the reactor. The Chem Systems process is capable of using any synthesis gas composition. The shift reactor and deacidification plant both are big consumers of energy.

The Chem Systems process is not restricted to the Texaco gasifier and at least two versions of the process are under development. One is a three-phase, bubbling-bed reactor that uses a solid proprietary catalyst in an inert hydrocarbon liquid. Synthesis gas is bubbled through the reactor medium, which provides close temperature control and permits an unusually close approach to the reaction equilibrium. Product methanol and the inert medium are immiscible and are separated easily within the reactor.

The alternative version is referred to as a liquid-entrained catalyst reactor and uses micron-sized catalyst particles suspended in the liquid to form a slurry. Catalyst slurry and synthesis gas may experience either cocurrent or countercurrent contact. The reactor liquid of choice is an aliphatic mineral oil in the C_{14} to C_{21} range. Aromatic oils and ethylene glycol also were tried with less success. The only major requirement imposed on the synthesis gas is sulfur removal before it goes into the reactor. This requirement can be met with conventional equipment. There is some variation in the product composition depending on the source (composition) of the synthesis gas, but Chem Systems says the methanol concentrations generally are greater than 90%. □